CONSTRAINING THE EXPOSURE TIME OF THE DARK DUNE MATERIAL ON MARS. D. Tirsch[1], M. Sowe[2], T. Kneissl[2] and R. Jaumann[1,2]. [1]Institute of Planetary Research, German Aerospace Center (DLR), Rutherfordstrasse 2, 12489 Berlin, Germany (daniela.tirsch@dlr.de; ralf.jaumann@dlr.de). [2]Institute of Geological Sciences, Freie Universitaet Berlin, Malteserstrasse 74-100, 12249 Berlin, Germany (mariam.sowe@fu-berlin.de; thomas.kneissl@fu-berlin.de).

Introduction: The numerous sand dunes that are located in Martian impact craters are not composed of bright quartz sand as it is typical for dunes on Earth. Instead, the Martian dunes consist of dark mafic sand that seems to originate from layers of volcanic ash, which were probably deposited in Noachian times [1]. At other places on Mars, distinct geologic units are suggested to be the source of the local dark dune-forming sediments, e.g. the Planum Boreum cavi unit at Ulympia Undae [2], wall strata at the Valles Marineris [3] or the Medusae Fossae Formation [4]. Here, we follow the ash layer hypothesis suggesting the dark sediments to be volcaniclastic sediments [1,5].

This material is unaltered, unoxidized, and presents its initial mineralogical composition, which is dominated by pyroxene and olivine, pointing to its volcanic origin [1, 6].]. In particular the preserved olivine, which is one of the least stable, hence most weatherable silicate minerals of igneous rocks, indicates that the sediment was neither exposed to significant amounts of liquid water under weak acidic conditions nor to oxidizing conditions. Hence, the layers of volcanic ash must have been protected from water by subsurface burial. In relative young Martian history these aeolian sediments were reactivated and remobilized by impact erosion and aeolian transport. Since then, they exist unaltered at the Martian surface, although the bulk of Mars's surface material is heavily affected by oxidation as demonstrated by the presence of iron oxides, phyllosilicates and carbonates.

The aim of our study is to determine the time of the material's re-exposure to the Martian atmosphere in order to constrain the decline of oxidizing conditions on Mars. Here, we determine the age of selected surfaces, which provides the maximum time of re-exposure of the dark dune material.

Background and Methods: Dark layers of volcanic ash are exposed at the walls of numerous impact craters. The material trickles out of these layers, runs down-wall to the crater's interior, and is deposited as aeolian dunes on the crater floor (Fig. 1, case A).

Other places of material exposures are large crater floors that are blotched by numerous smaller craters, a situation often observable in western Arabia Terra (Oxia Palus). The material emerges from these smaller craters that seem to cut the ash layer underneath the larger crater's floor (Fig. 1, case B and C). Spectral analyses of layer and dune material have confirmed their similarity [1, 7, 8].

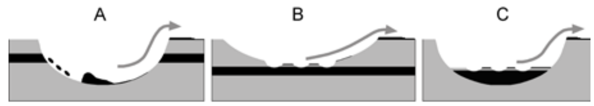

Fig. 1: *Types of dark aeolian sediment exposure in impact craters. A: Dark layer is exposed at crater wall; B: Dark layer is located beneath large crater floor and was cut by smaller craters; C: Dark sediments were deposited on a large crater floor, covered by regolith and finally cut by smaller craters [1].*

Analyzing the material's exposure time can be accomplished by dating the large crater floors that exhibit material exposure (exposure case B and C) or the ejecta of those impact craters showing dark layers at their walls (exposure case A). Absolute age dating was done by means of crater size-frequency distributions [9] whereby all primary craters located on a defined surface were counted using the software *crater tools* by [10] (Fig. 2) and further analyzed by utilizing a software tool named *craterstats* [11].

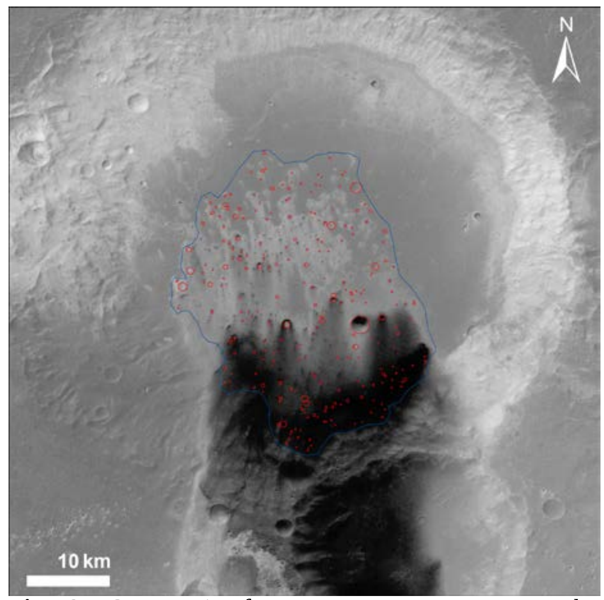

Fig. 2: *Crater size-frequency measurement on the floor of an exemplary crater near Mawrth Valles (18.89°N, 345.5°E, HRSC orbit 3297_0000). The floor of this 63 km crater is blotched by numerous smaller craters out of which the dark aeolian sediment emerges (exposure case B or C), representing a typical region that is used for dating. The emerging material builds dark dunes in the downwind direction.*

Finally, a *randomness analysis* [12] was performed on the data in order to rule out that secondary craters were counted and that the defined area is not homogeneous in its geologic history. This procedure provides the degree of clustering or ordering of the counted craters in a diagram. Values ranging inside the grey area (between -3 to 3) in the output diagram (see Fig. 3, top) represent neither clustered nor ordered craters and, hence, signify a good quality of the age dating. Details are described in [12].

Results and Discussion: This project is in its initial phase so that we cannot provide universal conclusions at this point. However, first results imply an Early to Late Hesperian time period (between 3.61 and 3.46 Ga at 4 dated surfaces) for the material exposure (see Fig. 3 for an example).

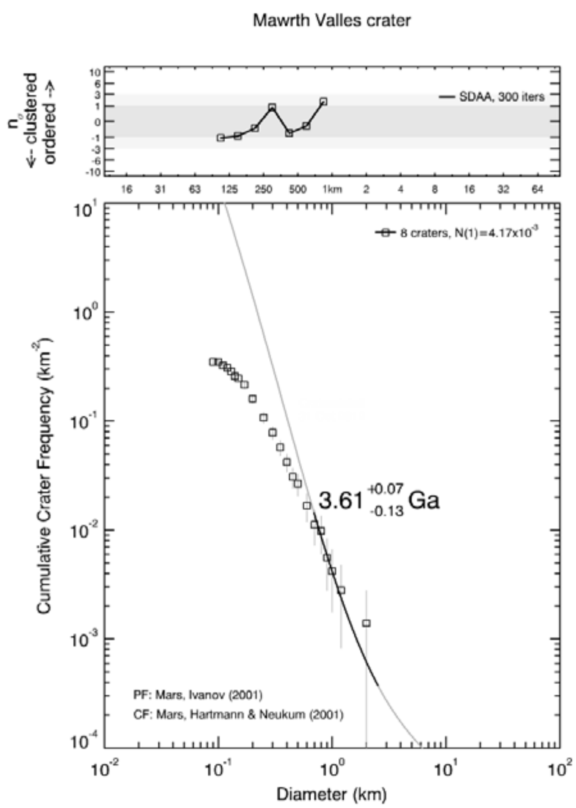

Fig. 3: Crater size-frequency distribution plot of a crater near Mawrth Valles (bottom) featuring the output diagram of the randomness analysis (top). The crater retention age of the surface where the dark sediment emerges (cf. Fig. 2) is estimated to be 3.61 Ga. The quality assessment (top diagram) certificates reliable results because the counted carters are neither clustered nor ordered.

This age range is plausible because it designates a time after the cessation of significant fluvial processes on the Martian surface [e.g., 13, 14, 15]. This surface age may not be mixed up with the actual dune age. The dunes themselves may be much younger because it takes much longer to transport the material and accumulate it into dunes. This age signifies the earliest possible time of material re-exposure from the subsurface at the given location. Some other dated crater ejecta and crater floors show Early to Middle Amazonian ages (between 1.16 and 2.89 Ga at 3 dated surfaces) and represent examples of later material exposure.

Since its exposure, the dark sand was disintegrated by mechanical weathering, has been transported by aeolian processes and was deposited as aeolian dunes [1]. The intra-crater dune material shows no further signs of alteration and was seemingly exposed at a time during which oxidizing conditions became less effective. At this point it must be mentioned that our study differs from studies of the Amazonian-aged north-polar dunes, which they comprise hydrated gypsum minerals pointing to aqueous weathering resulting from the proximity to the polar ice cap [e.g., 16, 17]).

In the process of study we aim to compile a conclusive sample quantity that defines the dark sediments exposure time and analyze the relationship between material properties, atmospheric conditions and Mars' redox state.

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